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(54) **FLIP-CHIP ON FLEX FOR HIGH PERFORMANCE PACKAGING APPLICATIONS**

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(52) U.S. Cl. **257/668; 257/723**

(58) Field of Search **257/723, 668, 257/700, 701**

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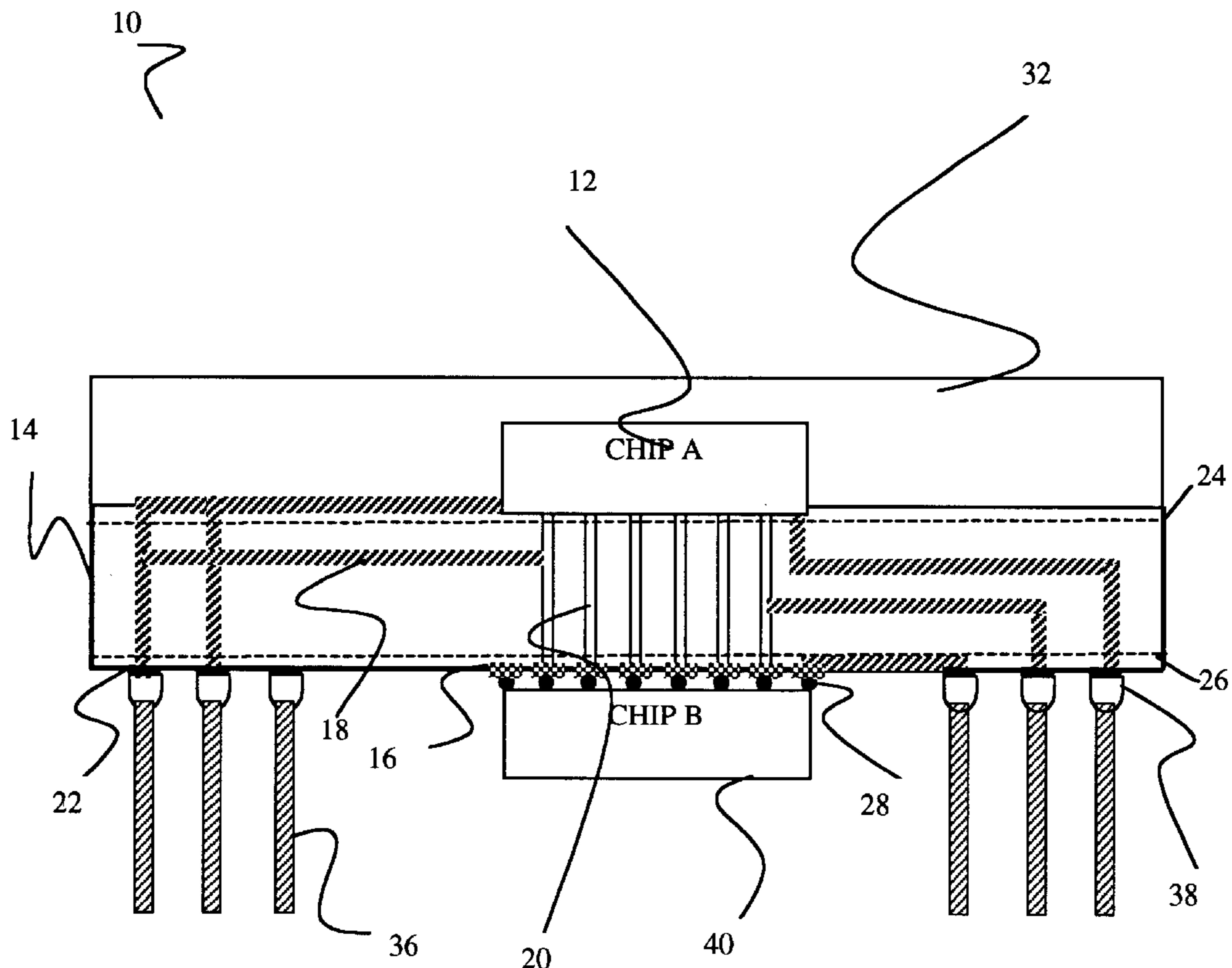
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(57) **ABSTRACT**

According to an embodiment of the invention, an integrated circuit (IC) package is provided that includes a flexible circuit board that has a first surface and a second surface. An integrated circuit mounted to the first surface of the flexible circuit board is provided. An electrical element is attached to the second surface of the flexible circuit board. Also, an encapsulant is attached to the flexible circuit board and the integrated circuit. The flexible circuit board includes at least one layer of dielectric that is no greater than approximately 35 microns thick. In another embodiment, the integrated circuit and the electrical element may be interchanged. A method is provided including attaching an encapsulant to an IC, forming a substrate from at least one layer of dielectric, attaching at least one electrical contact to the substrate, and attaching the substrate to the encapsulant so that the substrate is connected to the IC. Also, an electrical element may be attached with a flip-chip C4 (controlled collapsed chip connection) process.

24 Claims, 8 Drawing Sheets



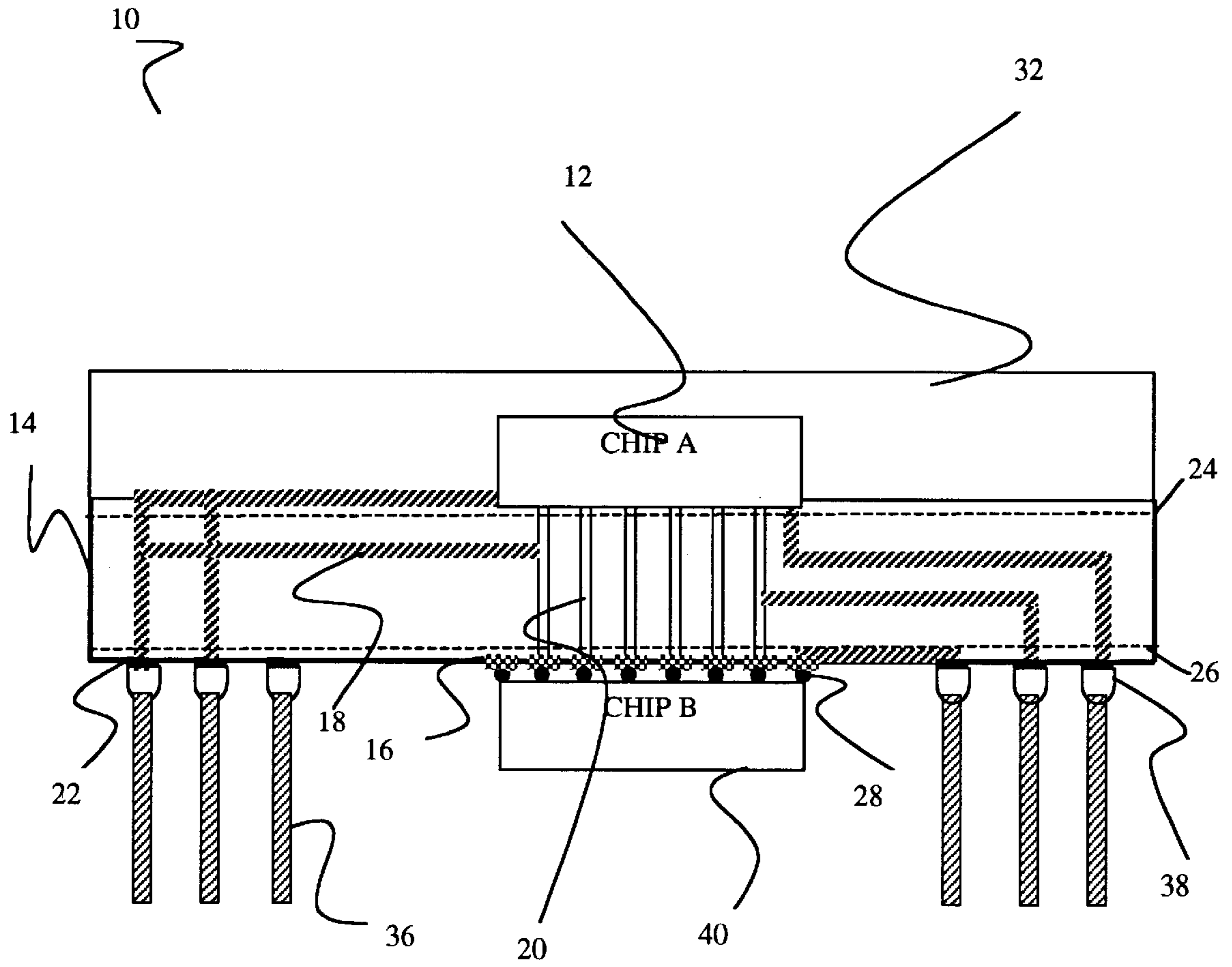


Figure 1

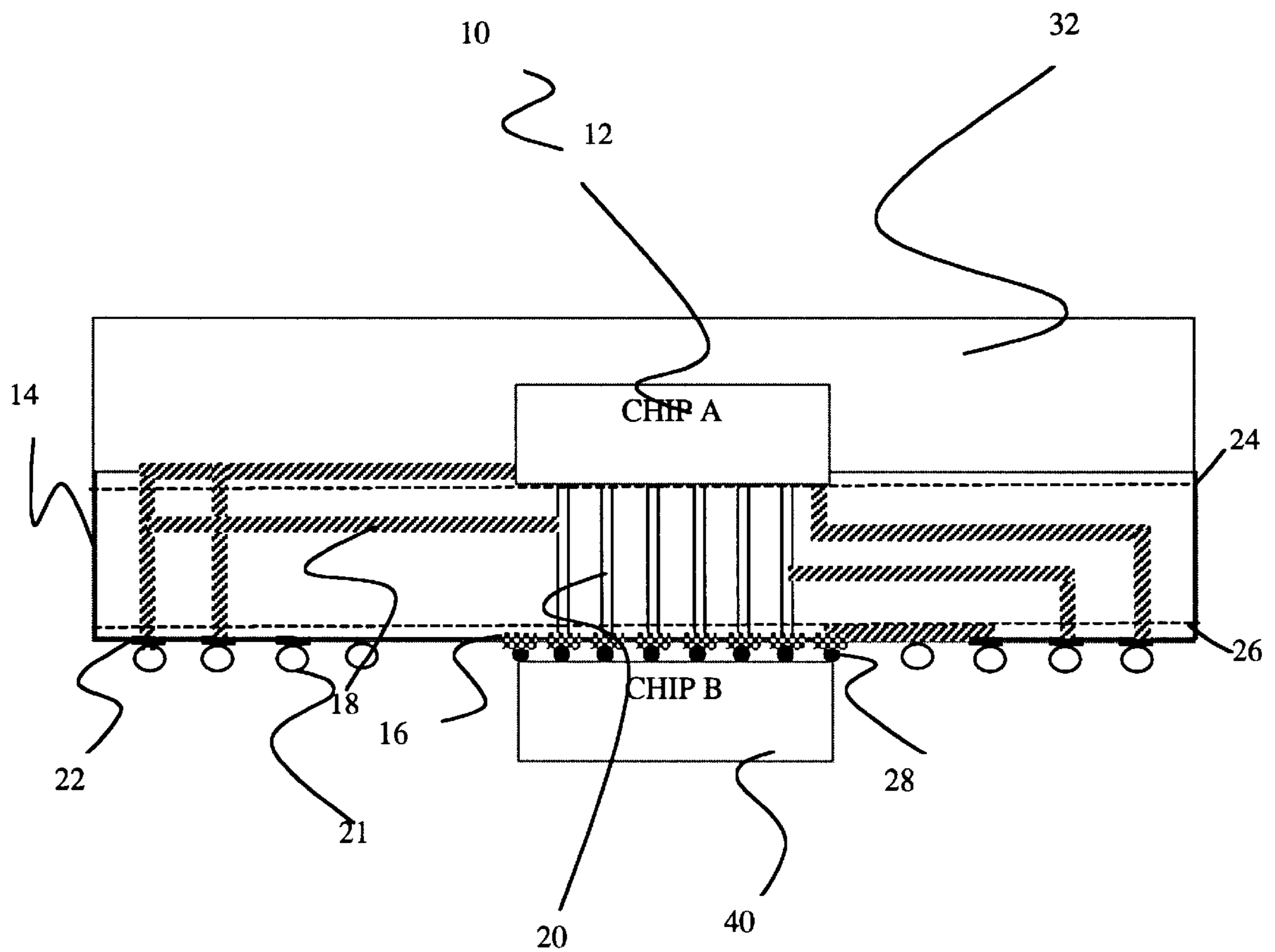


Figure 2

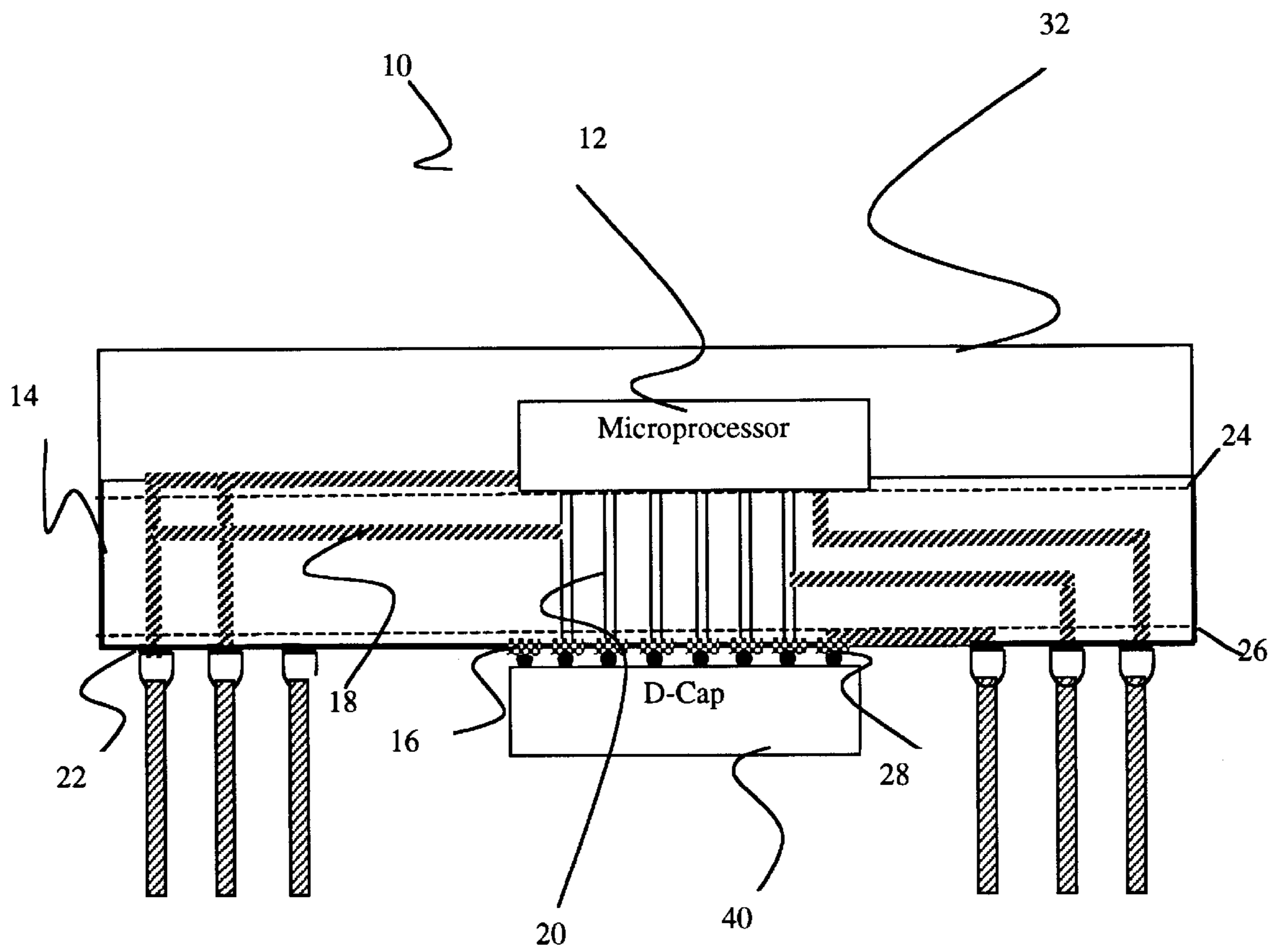
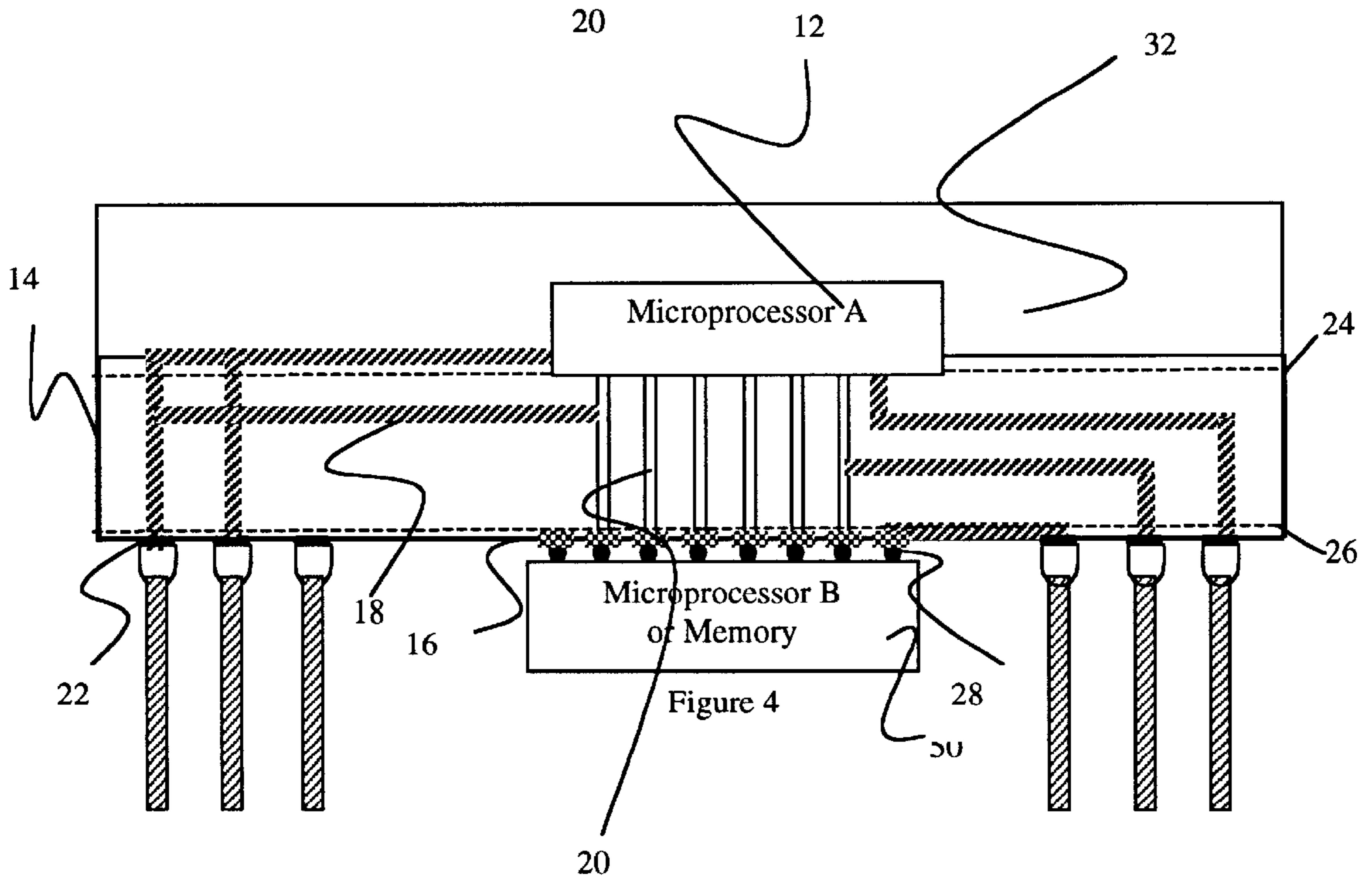
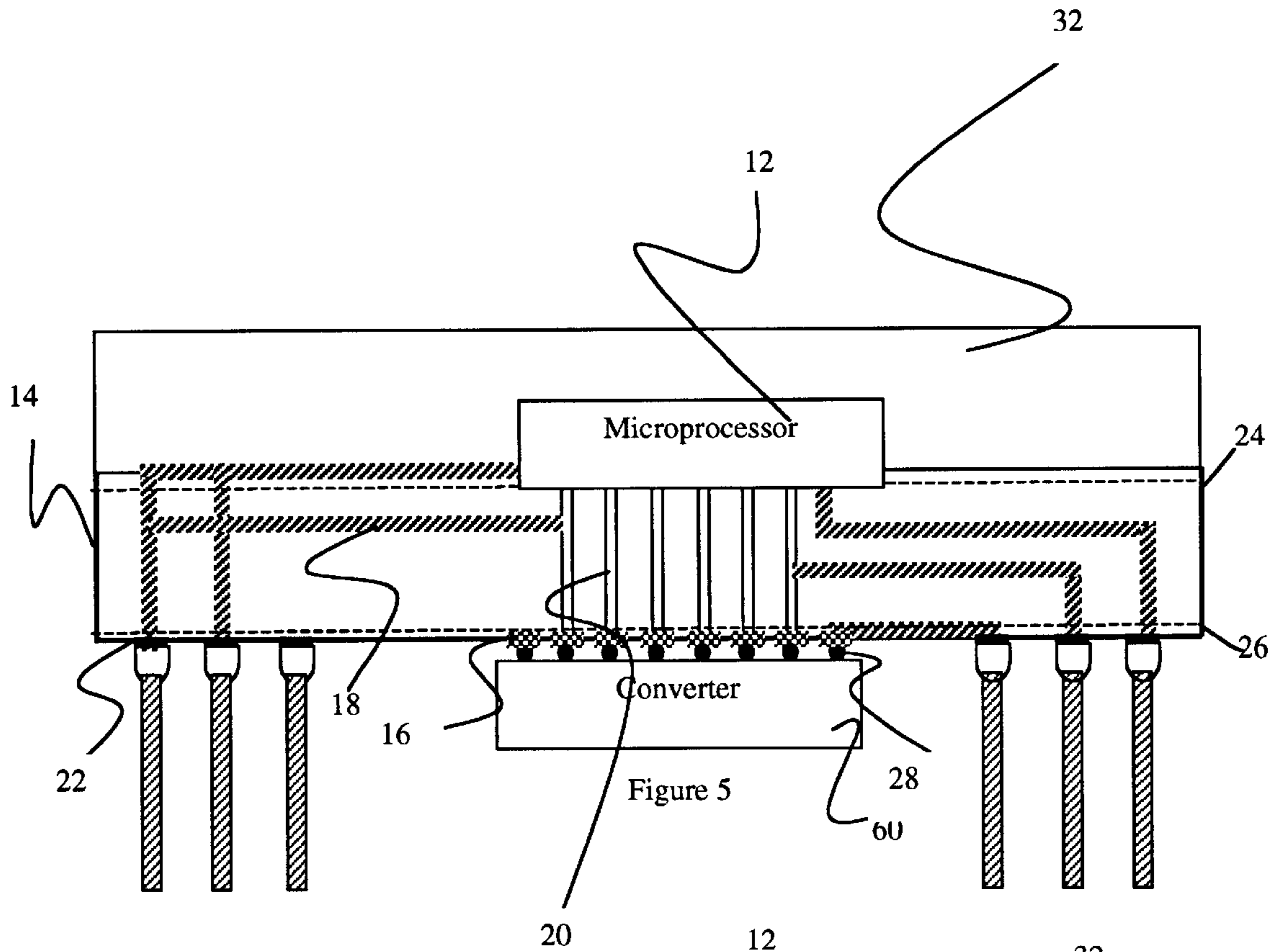


Figure 3



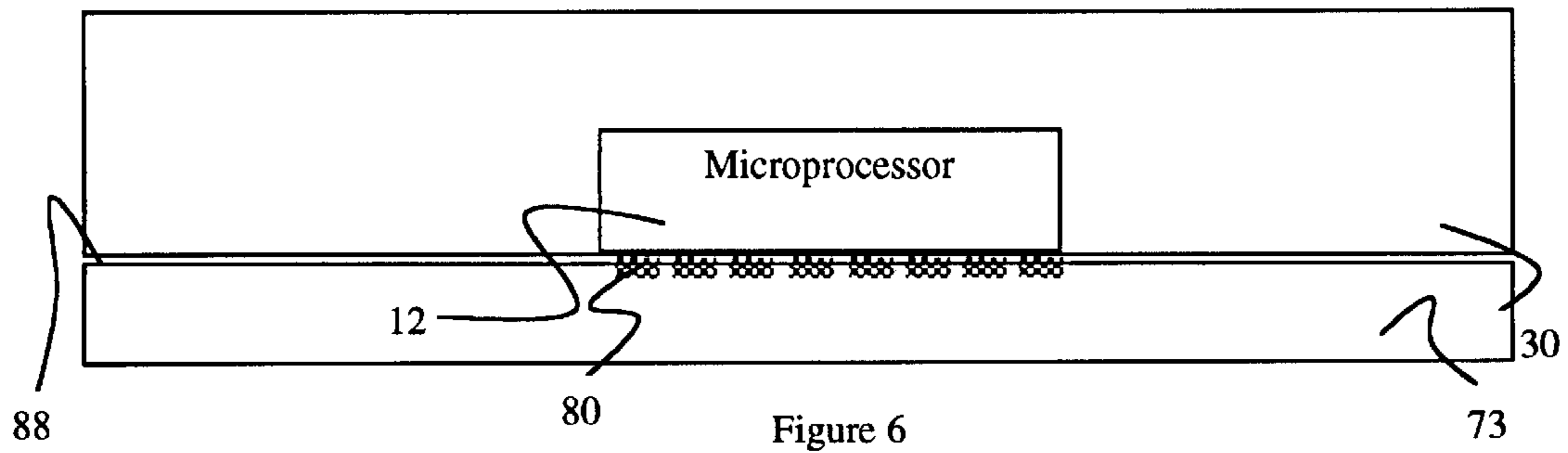


Figure 6

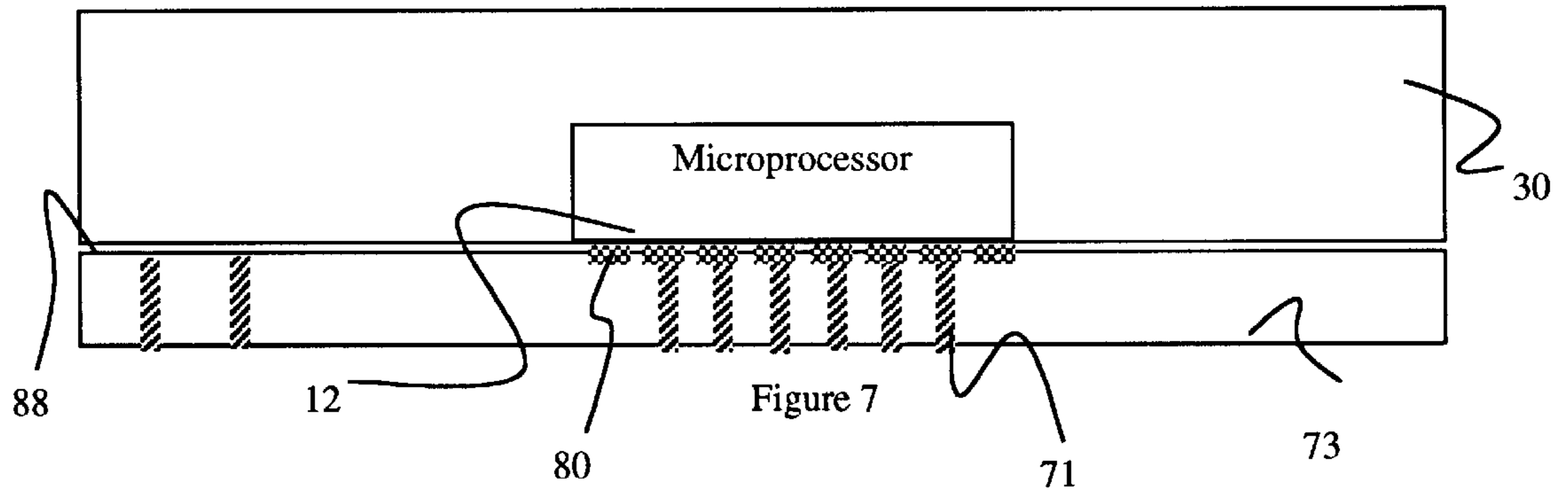


Figure 7

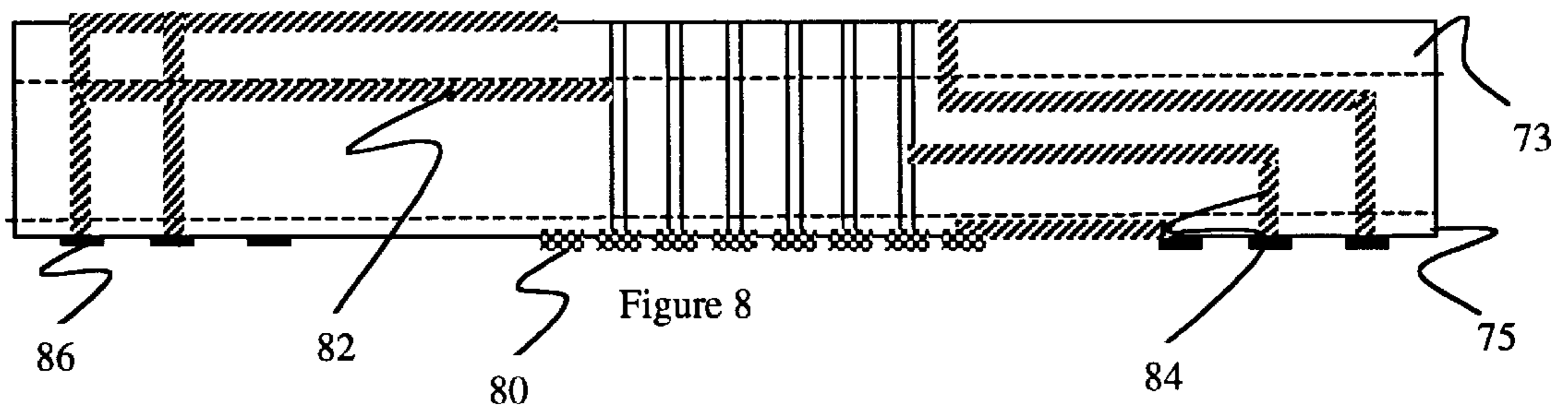


Figure 8

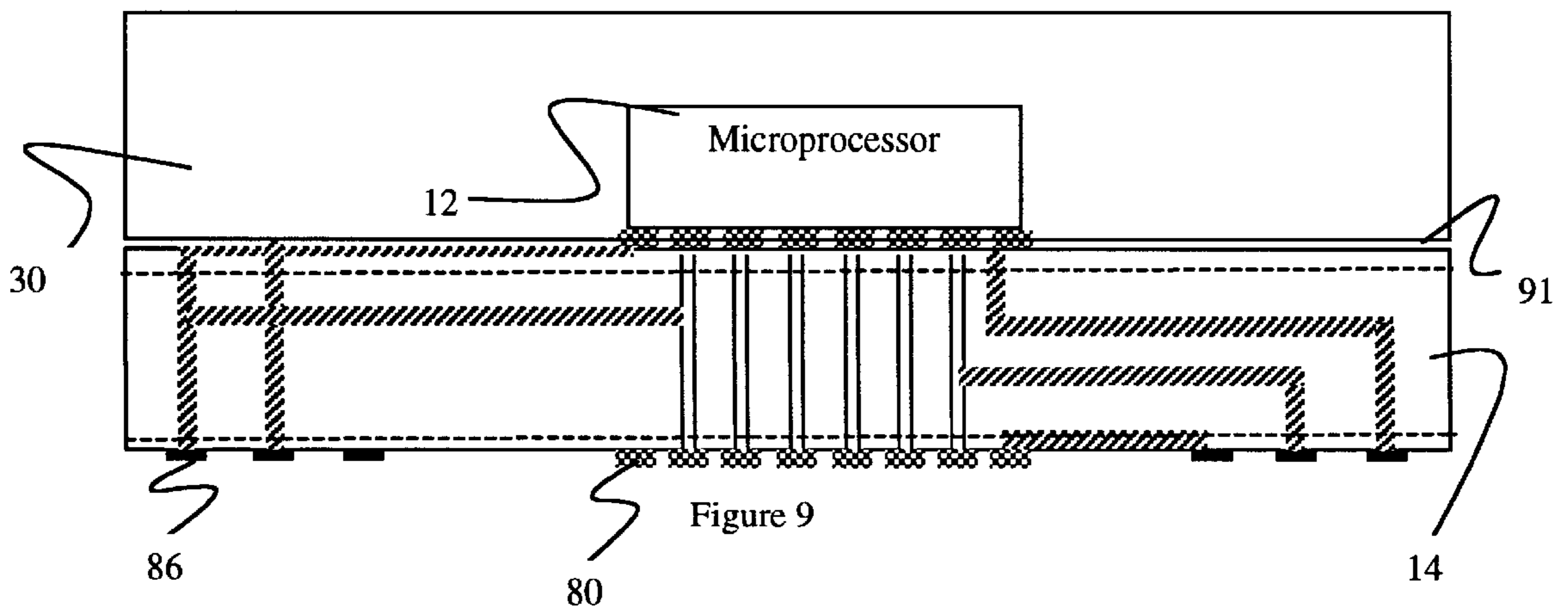


Figure 9

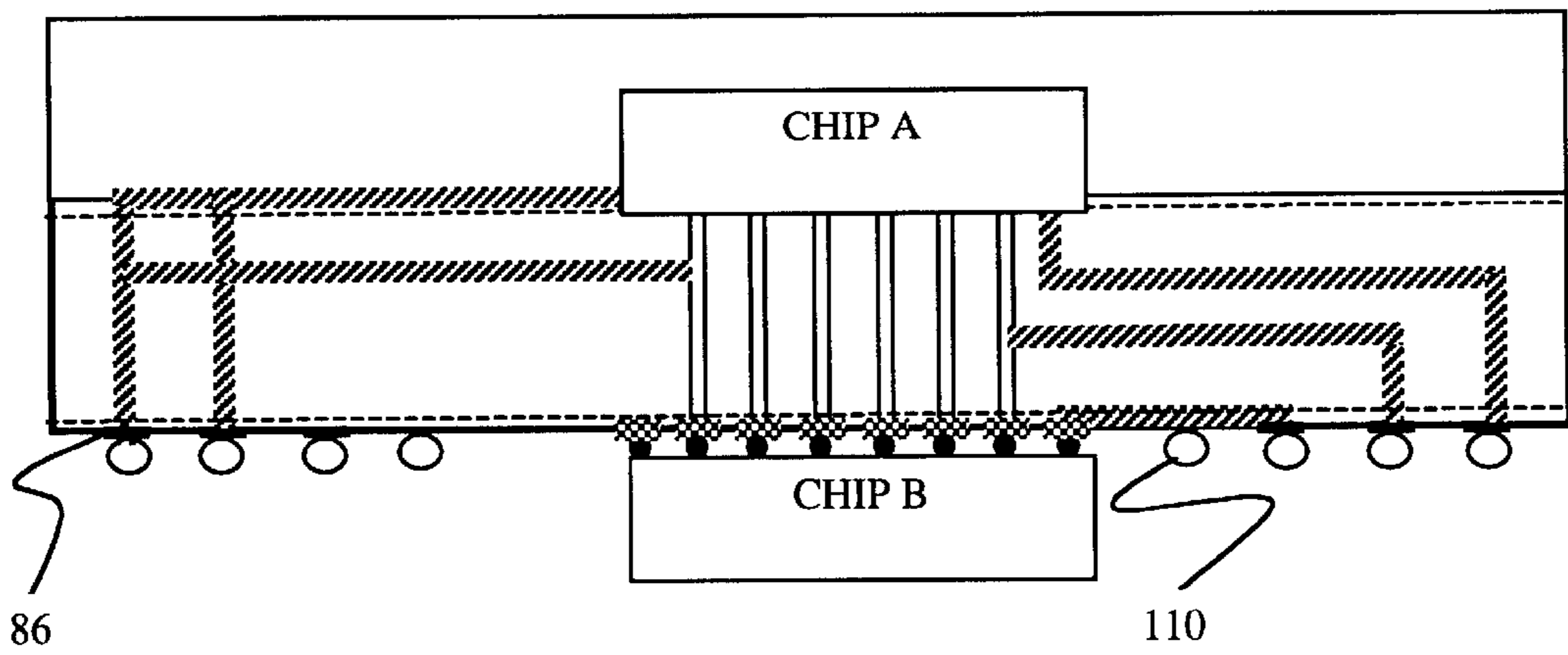
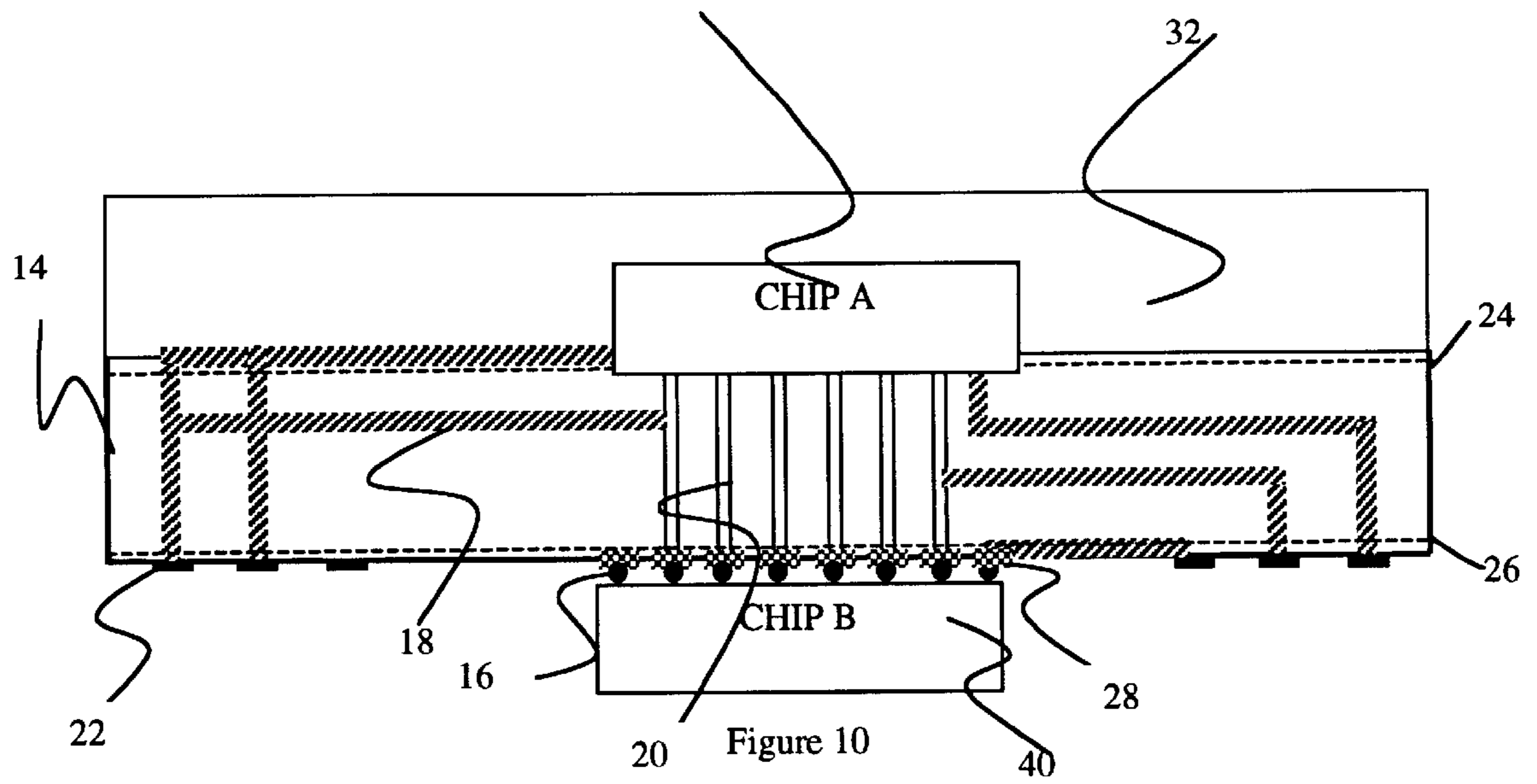


Figure 11

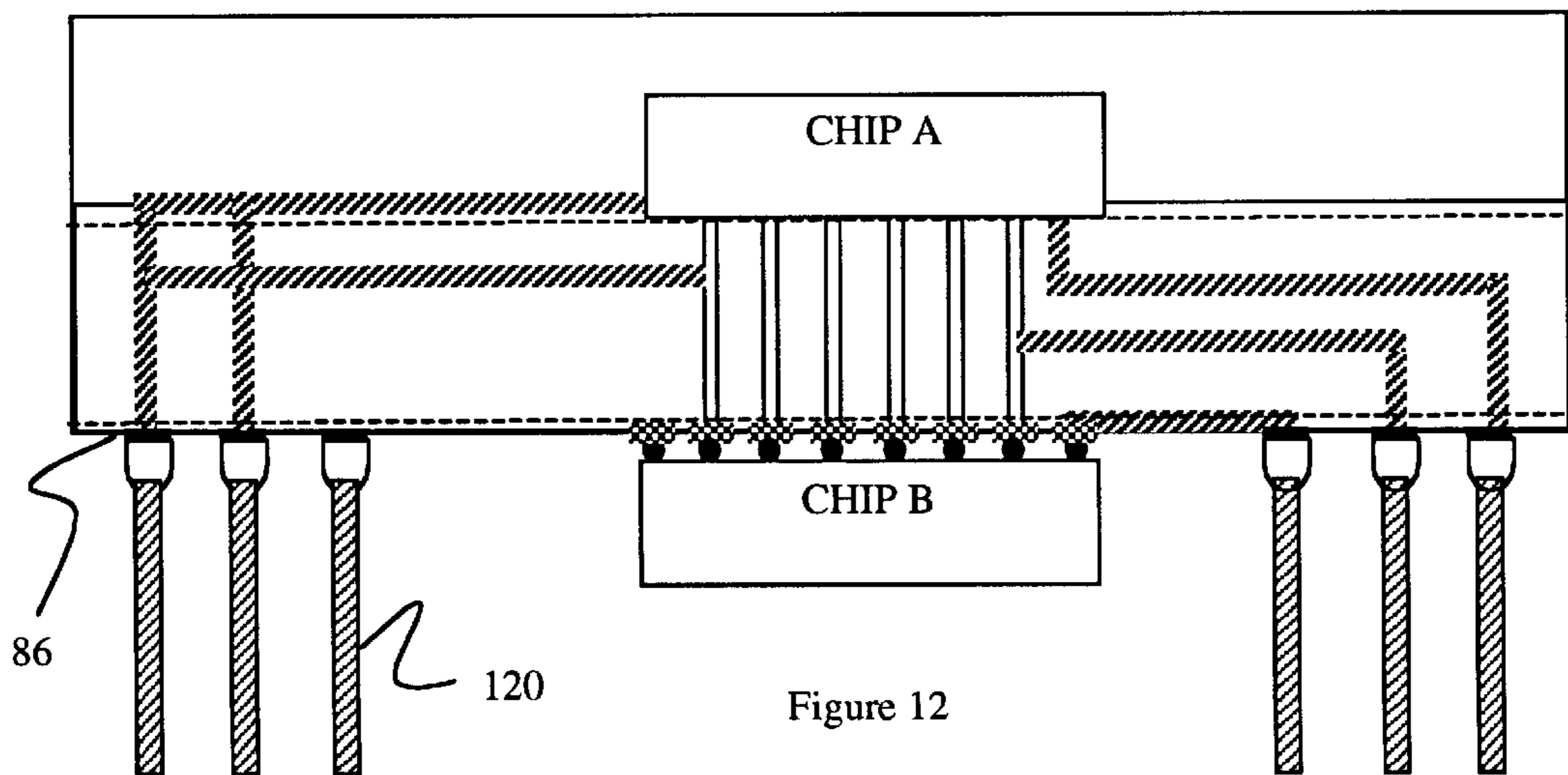
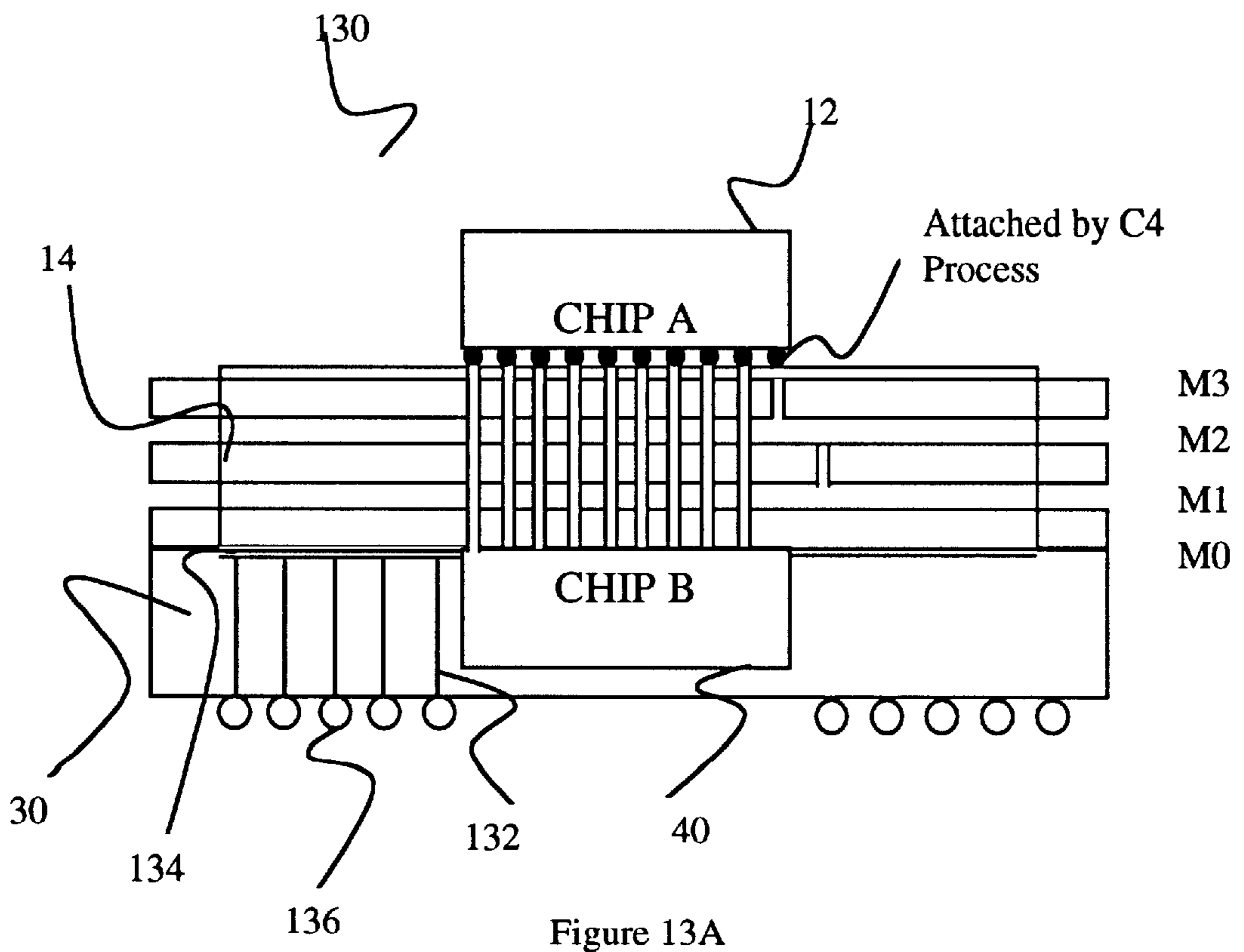
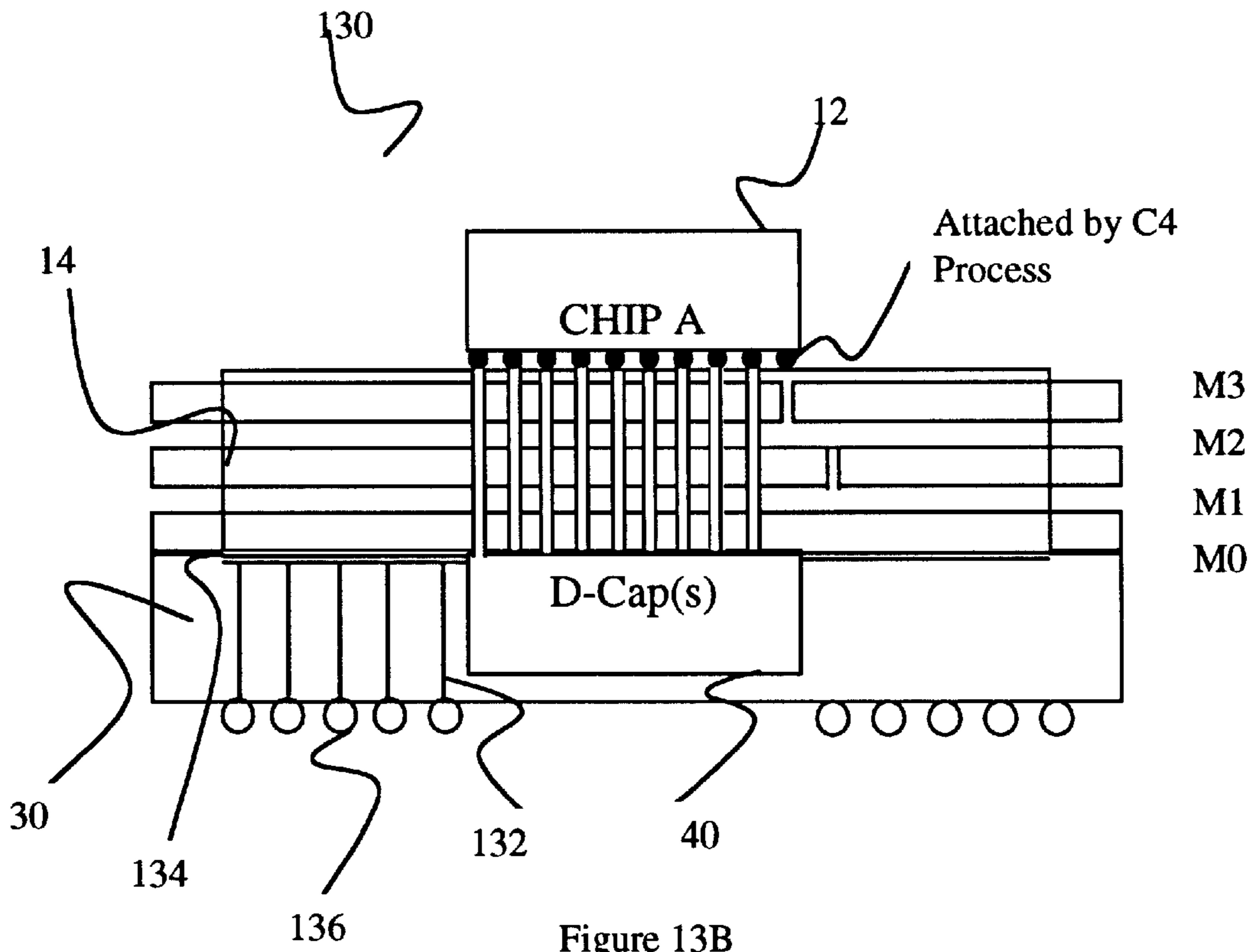
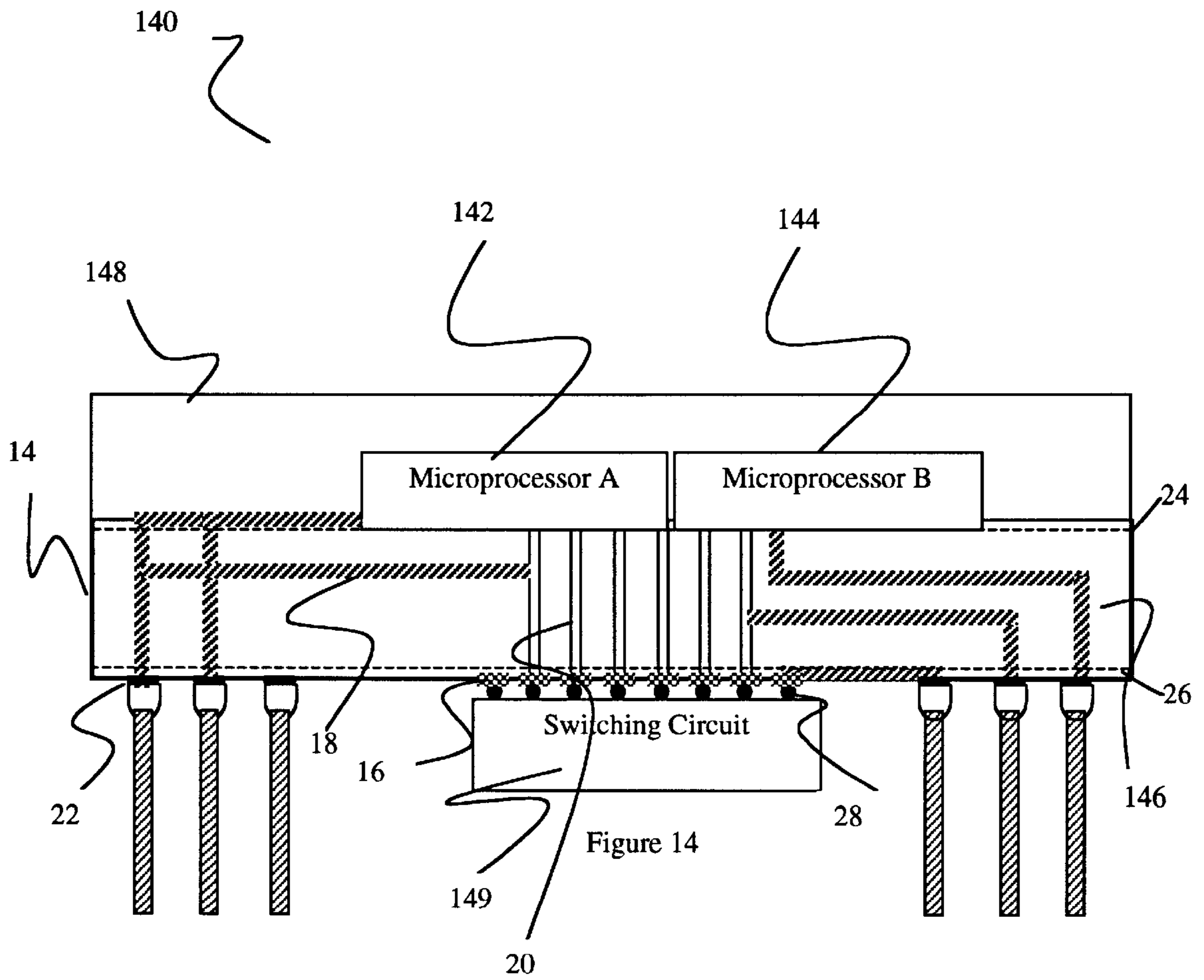


Figure 12





FLIP-CHIP ON FLEX FOR HIGH PERFORMANCE PACKAGING APPLICATIONS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an integrated circuit package that contains a flexible circuit board.

BACKGROUND INFORMATION

Integrated circuits (IC's) are typically assembled into a package that is mounted to a printed circuit board. The printed circuit board may be the motherboard of a computer. The integrated circuit may be mounted to a substrate and encapsulated with a plastic or epoxy material. A process known to those skilled in the art as flip-chip technology may be used to attach an IC to a substrate with the IC's I/O (input/output) side facing the substrate. One method that may be used to attach the flip-chip to the substrate is known as C4 attachment (controlled-collapse chip connection). With C4, solder bumps are placed on metal terminals on the flip-chip and a matching area of solder terminals on the substrate. The flip-chip is then aligned to the substrate, and all solder connections are made simultaneously by reflowing the solder. The substrate is typically a printed circuit board that has a number of pins, known as pin grid array (PGA), or solder balls, known as a ball grid array (BGA), that can be connected to the motherboard.

The substrate contains a number of routing traces, vias and solder pads that electrically connect the integrated circuit to the motherboard. The routing traces and solder pads may be separated by one or more layers of dielectric material.

The substrate/printed circuit board is fabricated before the integrated circuit is mounted to the substrate. The substrate must be thick enough to provide enough structural integrity to support the integrated circuit during the mounting process.

For CMOS (complementary metal oxide semiconductor) logic application, the IC chip integrated into a single package is typically accomplished through a multi-chip module using a 2-dimensional array. This type of package, however, suffers from longer inter-chip connection length. Some of the problems arising from such a package are: high propagation delay, high inductance, and cross-talking noise. In a case where a 3-dimensional array integration package is used, chips are stacked on top of each other and the inter-chip interconnection is achieved through edge wire bonding. A problem with this type of package is that the total I/O is limited.

In an array interconnect package, alignment and attachment are typically difficult to accomplish. For de-coupling needs, discrete de-coupling capacitors are typically mounted on the die-side or landside of the package after die attachment. For die-side capacitors, a larger package is typically required which increases cost. For landside capacitors, a typical package has a large die-to-capacitor separation and a large current loop, which leads to large inductance and degraded system performance.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 An embodiment of the present invention with two integrated circuits and a pin grid array (PGA).

FIG. 2 An embodiment of the present invention with two integrated circuits and a solder ball grid array (BGA).

FIG. 3 An embodiment of the present invention with a microprocessor and a decoupling capacitor with a pin grid array (PGA).

FIG. 4 An embodiment of the present invention with a microprocessor A and either a Microprocessor B or a memory with a pin grid array (PGA).

FIG. 5 An embodiment of the present invention with a microprocessor and a converter with a pin grid array (PGA).

FIGS. 6-10 A process for forming an embodiment of the present invention.

FIG. 11 Attachment of a BGA to an embodiment of the present invention.

FIG. 12 Attachment of a PGA to an embodiment of the present invention.

FIG. 13A An embodiment of the present invention with an integrated circuit connected on the die side and an integrated circuit encapsulated on the landside.

FIG. 13B An embodiment of the present invention with an integrated circuit connected on the die side a decoupling capacitor encapsulated.

FIG. 14 An embodiment of the present invention with two microprocessors encapsulated and a switching circuit with a PGA.

DETAILED DESCRIPTION

Referring to the figures, exemplary embodiments of the invention will now be described. The exemplary embodiments are provided to illustrate the invention and should not be construed as limiting the scope of the invention.

FIG. 1 shows an embodiment of an integrated circuit (IC) package 10 of the present invention. The package 10 may include an IC 12 that is mounted to a substrate 14. The substrate 14 may include a plurality of solder pads 16, routing traces 18, vias 20 and land pads 22 that connect a top substrate surface 24 with a bottom substrate surface 26. The top surface 24 is separated from a bottom surface 26 by one or more layers of dielectric. The dielectric may be a flexible (FLEX) material such as a polyimide. A polyimide is commonly used to construct flexible circuit boards. Although a flexible polyimide material is described, it is to be understood that other types of material may be employed including a more rigid material. Embedding the IC 12 in the FLEX and connecting it through micro-via technology can reduce the connection pitch and allow more input/output (I/O).

The integrated circuit 12 may be mounted to solder pads (not shown) of the substrate 14 with solder bumps (not shown) in a process commonly referred to as controlled collapsed chip connection (C4). The solder bumps may be structurally reinforced with an underfill epoxy material (not shown). The integrated circuit 12 may be encapsulated with an encapsulant 32. The encapsulant 32 may be a plastic or epoxy material. The encapsulant 32 may also be attached to the substrate 14 in a manner that seals the integrated circuit 12.

The package 10 may include a plurality of electrical contacts that are attached to corresponding land pads of the substrate 14. Each contact may include a pin 36 that is attached to a corresponding land pad 22 with a solder ball 38. The pins 36 can be soldered to solder pads or plated through holes of a printed circuit board (not shown), such as the motherboard of a computer. As an embodiment in FIG. 2 illustrates, the contacts may be solder balls 21 that are reflowed onto the motherboard using known ball grid array (BGA) processes.

The package 10 may also include an electrical element 40 mounted to the second surface 26 of the substrate 14. The

element **40** may be mounted to the substrate **14** using C4 flip-chip processes and under-fill protection (not shown). The element **40** may be a passive or active device. By way of example, as illustrated in FIG. 3, the integrated circuit **12** may be a microprocessor and the electrical element **40** may be a de-coupling capacitor. Alternatively, an electrical element **50** may be a memory device or another microprocessor (B) that is directly connected to the microprocessor **12** (A), as illustrated in FIG. 4. The direct attachment of both the microprocessor **12** and the memory device **50** to the substrate provides an assembly with a relatively short electrical path between the devices. The short path length reduces the inductance, which can be important for high-speed memory busses between the processor and memory. Alternatively, an electrical element **60** may be a power delivery circuit(s) that includes power management, regulator/converter, etc., as illustrated in FIG. 5.

FIGS. 6–9 show a method for attaching the substrate **14** to the integrated circuit **12**. As shown in FIG. 6, the encapsulant **30** can be initially molded onto the integrated circuit **12** in a manner that exposes the I/O pads of the circuit, and dielectric layer **73** is then attached to encapsulant **30** with an adhesive **88**. As illustrated in FIG. 7, one or more via holes **71** can be formed in the first layer of dielectric **73** through to the I/O pads. The dielectric **73** may be a polyimide material, although it is to be understood that other materials may be integrated into the substrate **14**. The via holes can be formed by laser drilling, mechanical drilling, etching or other techniques known in the art. The via holes **71** are then introduced with a conductive material. For example, electroplating or other methods may be used.

As illustrated in FIG. 8, another layer of dielectric **75** may be added to the first layer of dielectric **73**. Metal may be plated onto the dielectric layers **73** and **75** and etched to form the solder pads **80**, routing traces **82**, vias **84** and land pads **86** with known photolithography techniques. As illustrated in FIG. 9, the dielectric layers can then be attached to the integrated circuit **12** and substrate **14** with a layer of adhesive **91**. The adhesive **91** may have holes that expose the I/O pads of the integrated circuit **12**. A conductive epoxy can be inserted into the via holes to connect the I/O pads with the vias. FIG. 10 illustrates the addition of an electrical element **40**. The electrical element **40** may be mounted to the substrate **14** using flip-chip C4 processes. Solder balls **110** and pins **120** can be subsequently attached to the land pads **86** to complete the package **10**, as illustrated in FIG. 11 and 12.

In the process shown in FIGS. 6–9 the encapsulant **30** and integrated circuit **12** provide a mechanical support for the dielectric while the substrate **14** is being fabricated and attached to the circuit **12**. This support allows for a thinner layer of dielectric. By way of example, a dielectric layer no greater than approximately 35 microns can be used to fabricate the substrate **14**, which may be on the order of approximately 100 microns combined. Prior art substrates typically have layers of dielectric no thinner than 0.001 meters. The thinner dielectric layer shortens the lengths of the vias and reduces the inductance of the substrate **14**.

FIG. 13A shows an alternate embodiment **130** of a package **10** wherein the electrical element **40** is embedded into the encapsulant **30**. As illustrated in FIG. 13B, the electrical element **40** may be decoupling capacitor(s). Embedding a decoupling capacitor(s) in the FLEX can save the cost from FLEX yield loss and avoid having the capacitors attached to the surface of the package interfering with the assembly process. The substrate **14** can be attached to the element **40** and encapsulant **30**. The substrate **14** may be constructed

with the fabrication process shown in FIGS. 6–9. The substrate **14** may consist of a plurality of dielectric layers **M0**, **M1**, **M2** and **M3**. The encapsulant **30** may have a plurality of vias **132** and corresponding land pads **134** connected to the substrate **14**. The vias **132** may be formed by drilling via holes, plating the holes with metal and then applying a conductive epoxy.

Solder balls **136** may be attached to the land pads **134**. The solder balls **136** may be reflowed to attach the package **130** to a motherboard. An integrated circuit **12** may be mounted to the substrate **14**. The circuit **12** may be attached to the substrate with a flip-chip C4 process. The integrated circuit **12** may be enclosed by a lid (not shown) or other means.

FIG. 14 shows another embodiment **140** of a package **10** that has a first integrated circuit **142** and a second integrated circuit **144**. The integrated circuits **142** and **144** are attached to a substrate **146** and enclosed by an encapsulant **148**. The package **140** may have a plurality of contacts that can be attached to a motherboard.

The package **140** may also have a third integrated circuit **149** that is attached to the substrate **146**. The first **142** and second **144** integrated circuits may be microprocessors. The third integrated circuit **149** may be a switching circuit that provides a re-configurable high performance interconnect system.

The exemplary embodiments shown can provide fast, high current, low noise interconnect function between the ICs integrated inside a single package.

While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those ordinarily skilled in the art.

What is claimed is:

1. An integrated circuit (IC) package, comprising:

a flexible circuit board that has a first surface and a second surface;

at least one integrated circuit mounted to the first surface of the flexible circuit board, wherein the flexible circuit board comprises at least one layer of dielectric, the at least one layer of dielectric is no greater than approximately 35 microns thick;

an electrical element attached to the second surface of the flexible circuit board; and

an encapsulant that is attached to the flexible circuit board and the electrical element, wherein the first surface is electronically coupled with the second surface.

2. The IC package of claim 1, wherein the at least one layer of dielectric is a polyimide.

3. The IC package of claim 1, wherein the electrical element is selected from the group consisting of a capacitor, a microprocessor, a memory and a converter.

4. The IC package of claim 1, wherein the electrical element is a decoupling capacitor.

5. The IC package of claim 1, wherein the flexible circuit board further comprises at least one via.

6. The IC package of claim 1, wherein the flexible circuit board further comprises at least one routing trace.

7. The IC package of claim 1, further comprising at least one electrical contact attached to the second surface of the flexible circuit board.

8. The IC package of claim 7, wherein the at least one electrical contact comprises a pin.

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- 9. The IC package of claim 7 wherein the at least one electrical contact comprises a solder ball.
- 10. The IC package of claim 1, wherein the integrated circuit and the electrical element are interchanged.
- 11. The IC package of claim 1, wherein the electrical element is an integrated circuit.
- 12. The IC package of claim 1, wherein the total thickness of dielectric layers is no more than approximately 100 microns.
- 13. An integrated circuit (IC) package, comprising:
 - a flexible circuit board that has a first surface and a second surface;
 - at least one integrated circuit mounted to the first surface of the flexible circuit board, wherein the flexible circuit board comprises at least one layer of dielectric;
 - an electrical element attached to the second surface of the flexible circuit board; and
 - an encapsulant that is attached to the flexible circuit board and the electrical element, wherein the first surface is electronically coupled with the second surface,
 wherein the total thickness of dielectric layers is no more than approximately 100 microns.
- 14. The IC package of claim 13, wherein the at least one layer of dielectric is no greater than approximately 35 microns thick.

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- 15. The IC package of claim 13, wherein the at least one layer of dielectric is a polyimide.
- 16. The IC package of claim 13, wherein the electrical element is selected from the group consisting of a capacitor, a microprocessor, a memory and a converter.
- 17. The IC package of claim 13, wherein the electrical element is a decoupling capacitor.
- 18. The IC package of claim 13, wherein the flexible circuit board further comprises at least one via.
- 19. The IC package of claim 13, wherein the flexible circuit board further comprises at least one routing trace.
- 20. The IC package of claim 13, further comprising at least one electrical contact attached to the second surface of the flexible circuit board.
- 21. The IC package of claim 20, wherein the at least one electrical contact comprises a pin.
- 22. The IC package of claim 20, wherein the at least one electrical contact comprises a solder ball.
- 23. The IC package of claim 13, wherein the integrated circuit and the electrical element are interchanged.
- 24. The IC package of claim 13, wherein the electrical element is an integrated circuit.

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